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The CCAT Software System

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Abstract. CCAT will be a 25-meter telescope for submillimeter astronomy located at 5600 m altitude on Cerro Chajnantor in northern Chile. CCAT will combine high sensitivity, a wide field of view, and a broad wavelength range (0.35 to 2.1 mm) to provide an unprecedented capability for deep, large-area multicolor submillimeter surveys. It is planned to have a suite of instruments including large format KID cameras, a large heterodyne array and a KID-based direct detection multi-object spectrometer. The remote location drives a desire for fully autonomous observing coupled with data reduction pipelines and fast feedback to principal investigators.

1. Key Drivers for Software Design

CCAT (Woody et al. 2012; Glenn et al. 2013) has two key drivers for the software design:

Instrument Data Rates: Next generation sub-millimeter cameras with 40,000 to 65,000 detectors and reading out at 3 kHz can generate data at a peak rate of ~ 7 Gbps and generate 30 to 60 TB per day.

Remote Location: The Observatory is located on Cerro Chajnantor above the ALMA plateau at an altitude of 5600 m. Given the remoteness of the site, the Observatory is designed to operate autonomously to the extent possible and support remote control from the base facility in San Pedro de Atacama and/or partner sites.

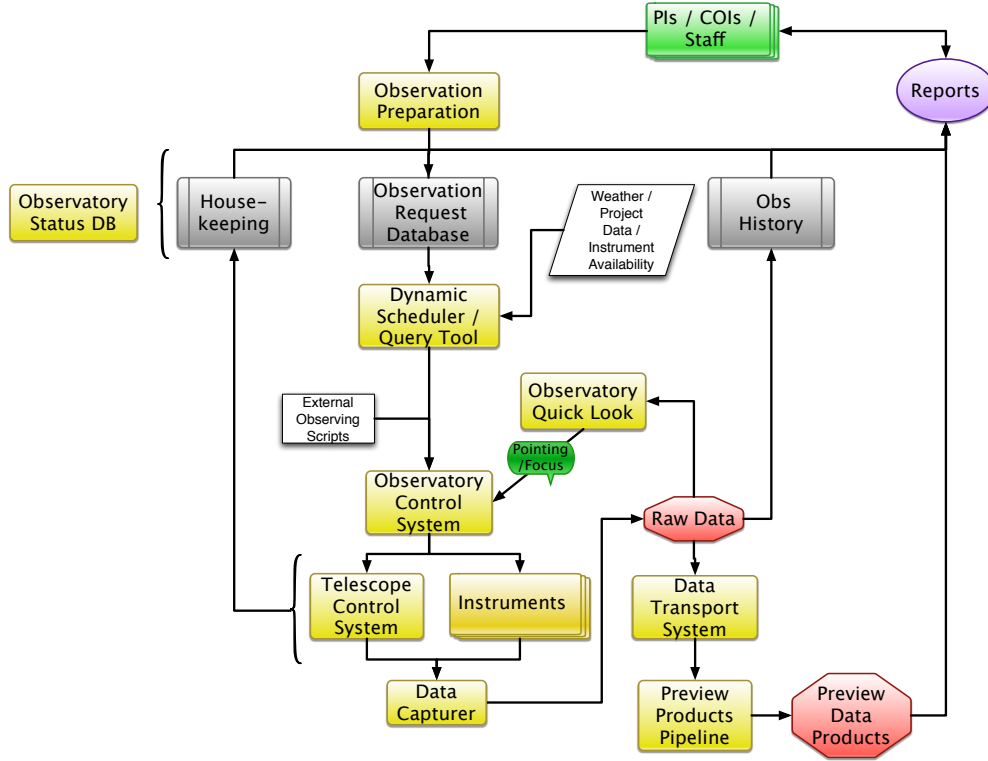


Figure 1. Observations are prepared and stored by the OT and queried by the scheduler. The OCS executes observations and the Data Capturer collates the resulting data. The files are then transferred to the base facility and preview products are generated for review by the PI.

2. Proposed Instrumentation

The CCAT project has identified four major instruments to achieve its science goals. SWCam (Stacey et al. 2013) is a 50,000-70,000 detector camera operating in the $350\ \mu\text{m}$ and $450\ \mu\text{m}$ windows with a short-wavelength goal of $200\ \mu\text{m}$. LWCam (Golwala et al. 2013) is a 40,000 detector camera operating in 5-6 bands between $750\ \mu\text{m}$ and $2.1\ \text{mm}$ with a long-wavelength goal of $3.3\ \text{mm}$. X-Spec (Bradford et al. 2013) is a multi-object spectrometer with ~ 100 beams on the sky, each covering a frequency range of 190-520 GHz in two bands simultaneously with spectral resolutions between 400 and 700. CHAI (Goldsmith et al. 2012) is a 2×64 -element heterodyne array operating in the $600\ \mu\text{m}$ and $350\ \mu\text{m}$ bands.

3. Software Systems

An outline of the CCAT software and how the systems are connected is given in Fig. 1. This section provides more detail on individual components.

Observation Preparation: CCAT is exploring the feasibility of building onto existing submillimeter observation preparation tools (OTs) such as the ALMA-OT (Bridger

et al. 2012), the JCMT-OT (Folger et al. 2002) and Herschel-Spot (Riedinger 2009; Frayer et al. 2007). OT support of CCAT’s planned multi-object spectrograph instrument will require the addition of new capabilities to whichever OT solution is chosen.

Dynamic Scheduler: CCAT is a flexibly-scheduled telescope and will use a dynamic scheduler to determine what should be observed next, similar to those employed at other sub-millimeter telescopes such as JCMT (Economou et al. 2002; Adamson et al. 2004) and ALMA (Lucero & Farris 2007). The Scheduler will have a manual mode allowing an observer to query the system but the aim is for the scheduler to continually monitor the telescope environment and observing queue and ensure that the best Minimum Schedulable Block (MSB) (see e.g. Jenness & Economou 2011, for a more detailed description of an MSB) for the current conditions is always observed and the telescope is never idle. One complication in the sub-millimeter is the paucity of flux calibrators in the sub-millimeter sky. This sometimes requires that the flux calibrator is observed some time after the observation that requires it. The scheduler must keep track of the calibrations requirements and schedule them when appropriate.

Observation Execution: The Observatory Control System (OCS) provides command and control and monitoring of all observatory systems relating to observing. It uses a lightweight scripting execution engine with guaranteed latencies. The OCS is influenced by experience from earlier telescopes such as CBI, QUIET and the OVRO 40m (see e.g. Bischoff et al. 2013).

Data Capturer: The Data Capturer (DC) takes the output from the instruments, telescope control system and other systems and collates them into output data files. The large data rates, and the need to support simultaneous acquisition by multiple instruments, led us to a distributed approach where each subsystem writes its own data files to disk and the DC writes a small header file with hierarchical linkage to the individual files.

Data Transport: There will only be limited disk space at the summit and data will immediately be transferred to the Base Facility via a fiber connection.

Preview Products Pipeline: Raw data will be shipped to the CCAT Data Archive on disks as network bandwidth is prohibitive. To provide data quality assessment a pipeline will run at the Base Facility to generate usable products suitable for remote observation assessment.

Data Reduction Challenges: Reducing data from continuum cameras with data rates 100 times larger than current instruments, such as SCUBA-2 on JCMT (Holland et al. 2013), will be challenging. Some thoughts on this can be found in Marsden et al. (2014). Similarly CHAI has a data rate 64 times larger than the HARP instrument on JCMT (Buckle et al. 2009).

Observation Management: The remote autonomous operation requires that there is a robust system in place for tracking Minimum Schedulable Blocks and associated observations. Time accounting will be automated by default with the ability to reject observations either automatically, via QA assessment, or from human intervention. PIs will be able to track the status of their project at any time and modify their Science Program based on feedback from observations already taken.

Observatory Status: All information generated by the observatory will be logged permanently in an Observatory Status Database. The OSD will store instrument house keeping data (possibly 0.5 TB/day), observation management information, calibration history and other digital data.

Survey Pipeline: Not explicitly listed in Fig. 1, the processing of survey data will be coordinated through the CCAT Data Archive (CDA). Reduced data products will be archived permanently and will be made available via VO protocols once the proprietary period expires. The CDA will also endeavor to reduce PI data if standard observing modes were used.

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